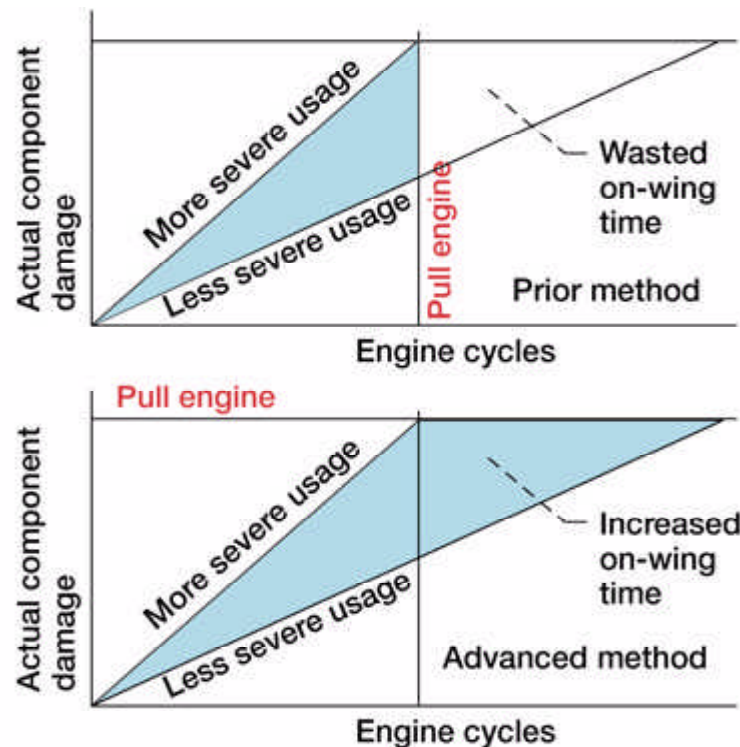


# Data-Mining Toolset Developed for Determining Turbine Engine Part Life Consumption

The current practice in aerospace turbine engine maintenance is to remove components defined as life-limited parts after a fixed time, on the basis of a predetermined number of flight cycles. Under this schedule-based maintenance practice, the worst-case usage scenario is used to determine the usable life of the component. As shown in the top graph, this practice often requires removing a part before its useful life is fully consumed, thus leading to higher maintenance cost. To address this issue, the NASA Glenn Research Center, in a collaborative effort with Pratt & Whitney, has developed a generic modular toolset that uses data-mining technology to parameterize life usage models for maintenance purposes.



*Top: Current schedule-based maintenance approach. Bottom: Condition-based maintenance approach enabled by data-mining toolset.*

Long description of figure Top: Current schedule-based maintenance approach removes a part after a predetermined number of flight cycles, resulting in wasted on-wing life.

Bottom: Condition-based maintenance approach removes a part at a predetermined damage level, resulting in full utilization of safe on-wing life.

The toolset enables a "condition-based" maintenance approach, where parts are removed on the basis of the cumulative history of the severity of operation they have experienced. The toolset uses data-mining technology to tune life-consumption models on the basis of operating and maintenance histories. The flight operating conditions, represented by measured variables within the engine, are correlated with repair records for the engines, generating a relationship between the operating condition of the part and its service life. As shown in the bottom graph, with the condition-based maintenance approach, the life-limited part is in service until its usable life is fully consumed. This approach will lower maintenance costs while maintaining the safety of the propulsion system.

The toolset is a modular program that is easily customizable by users. First, appropriate parametric damage accumulation models, which will be functions of engine variables, must be defined. The tool then optimizes the models to match the historical data by computing an effective-cycle metric that reduces the unexplained variability in component life due to each damage mode by accounting for the variability in operational severity. The damage increment due to operating conditions experienced during each flight is used to compute the effective cycles and ultimately the replacement time. Utilities to handle data problems, such as gaps in the flight data records, are included in the toolset.

The tool was demonstrated using the first stage, high-pressure turbine blade of the PW4077 engine (Pratt & Whitney, East Hartford, CT). The damage modes considered were thermomechanical fatigue and oxidation/erosion. Each PW4077 engine contains 82 first-stage, high-pressure turbine blades, and data from a fleet of engines were used to tune the life-consumption models. The models took into account not only measured variables within the engine, but also unmeasured variables such as engine health parameters that are affected by degradation of the engine due to aging. The tool proved effective at predicting the average number of blades scrapped over time due to each damage mode, per engine, given the operating history of the engine. The customizable tools are available to interested parties within the aerospace community.

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